Vectorcardiographic T loop analysis in ischaemic heart disease

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Vectorcardiographic T loops were studied in 100 patients undergoing selective coronary angiography for the evaluation of chest pain. The T loops were recorded simultaneously with an electrocardiogram before and after the completion of a standard Master's two-step exercise test. A positive ischaemic change in the electrocardiogram was greater than or equal to 1 mm of flat ST segment depression, while a positive ischaemic change in the vector T loop was a length/width ratio of less than or equal to 2·6:1 or an increase in the ST segment opening of greater than or equal to 10 mm (0·1 mV). Myocardial ischaemia was assumed to correlate with the appearance of the coronary angiograms.

Eleven patients had minimal coronary narrowing of less than 50 per cent occlusion of a major vessel and were excluded from the study since the presence or absence of ischaemia was equivocal. The remaining 89 patients had either no coronary artery disease (30 patients) or severe coronary artery disease (59 patients).

The electrocardiogram correlated with the coronary angiogram in 64 per cent of the cases (57/89 correct) and the vectorcardiogram in 80 per cent of the cases (71/89 correct). In patients with severe coronary artery disease the vector T loops were ischaemic in 81 per cent of the cases (49/59), but the electrocardiogram revealed ischaemia in only 59 per cent of the patients (35/59).

It is concluded that vectorcardiographic T loop analysis is a useful, relatively simple, and more accurate method of determining the presence of ischaemic heart disease than the electrocardiogram.

The Master's postexercise electrocardiogram has been widely accepted as an accurate method of detecting ischaemic heart disease (Master and Rosenfeld, 1961). However, despite many revisions of criteria, a high percentage of both false positive and false negative results have been reported (Hurst and Logue, 1970). In a recent study, 42 per cent of patients with angina and documented coronary artery disease had a negative postexercise electrocardiogram (Most, Kemp, and Gorlin, 1969). Vectorcardiographic T loop changes with myocardial ischaemia have been described by Chou and others (Chou, Helm, and Lach, 1964; Al Abdulla, Dicovsky, and Zimmerman, 1969). Al Abdulla *et al.* (1969) have shown that the resting vectorcardiographic T loop appearance correlates well with the angiographic appearance of the coronary arteries. Changes in the vectorcardiographic T loop with treadmill exercise have also been recorded in both normals and in patients with

myocardial ischaemia (Isaacs *et al.*, 1966, 1968). In the present study, the Master's exercise technique was applied to vectorcardiographic T loop recordings, and the resting and postexercise T loop changes were correlated with the presence or absence of demonstrable coronary artery disease. To our knowledge, this is the first time such a study has been done.

Materials and methods
One hundred consecutive patients undergoing selective coronary angiography for the evaluation of chest pain were studied. Patients with valvular heart disease or pulmonary hypertension were excluded from the study. The patient ages ranged from 27 to 68 years. There were 76 men and 24 women. Vectorcardiographic T loops were recorded simultaneously with an electrocardiogram before and after the completion of a standard Master's (Master and Rosenfeld, 1961) two-step exercise test. Vectorcardiograms were recorded with a Hewlett-Packard 157 A Vector Programmer using the Frank (1956) leads system. T loops were recorded in both horizontal and frontal planes

using a 0·2 mV standard. Technical difficulties related to diaphragmatic movement after exercise precluded recording of sagittal plane loops. ST segment opening was measured in mm (1 cm equals 0·01 mV). The length-width ratios were determined by the method of Chou *et al.* (1964) using horizontal and frontal planes. Length-width ratio was determined by dividing the greatest length in either plane by the greatest width in either plane. A positive ischaemic change in the vectorcardiographic T loop was a length-width ratio of less than or equal to 2·6:1 or an increase in ST segment opening of greater than 10 mm in the postexercise tracing. A positive ischaemic change in the electrocardiogram was greater than 1 mm of flat ST segment depression in the post-exercise tracing (Most *et al.*, 1969).

Selective coronary arteriograms were performed using the Judkins (1967) technique. 16 mm or 35 mm cine and static films in two planes were obtained. The coronary arteriograms were classified according to Demany, Tambe, and Zimmerman (1967) with 3+ narrowing representing greater than 50 per cent narrowing of a major vessel. Since greater than 50 per cent obstruction of a major vessel is required before significant reduction of coronary blood flow occurs (Sewell, 1967), patients with 1+ or 2+ disease (50 per cent narrowing or less) were excluded from the study. Eleven patients had such minimal narrowing and were excluded since the presence or absence of ischaemia was equivocal. The remaining 89 patients had either no coronary artery disease (30 patients) or severe coronary artery disease (59 patients).

Myocardial ischaemia was assumed to correlate with the appearance of the coronary angiograms. The diagnostic accuracy of the Master's postexercise electrocardiogram and the postexercise vectorcardiogram was determined by comparing these recordings with the coronary arteriogram.

Results

The overall accuracy of the electrocardiogram was 64 per cent (57/89 correct) and the vectorcardiogram was 80 per cent (71/89 correct). In patients with no coronary artery disease, the accuracy of the postexercise electrocardiogram was 73 per cent (22/30 negative), while the postexercise vectorcardiogram was 77 per cent correct (23/30 negative). In patients with severe coronary disease, the accuracy of the postexercise electrocardiogram was only 59 per cent (35/59 positive). The postexercise vectorcardiogram, however, was 81 per cent correct (48/59 positive) in patients with severe disease. The Table lists the clinical features of 13 patients with demonstrable severe coronary artery narrowing who had false negative Master's postexercise electrocardiogram but abnormal (positive) vectorcardiographic T loops. Fig. 1 is a diagram of a normal resting, normal postexercise,

**TABLE**   *Clinical summary of 13 patients with severe coronary artery disease*

Case No.	Age	Sex	Digitalis	Coronary angiogram*	Electro-cardiogram	Vector-cardiogram	Vector-cardiogram L/W	Vector-cardiogram ST
1	53	M	o	Anterior descending coronary artery	Normal	Abnormal	+†	o
2	55	M	o	Right coronary artery; circumflex coronary artery	,,	,,	+	o
3	51	M	o	Anterior descending coronary artery; circumflex coronary artery	,,	,,	+	+
4	54	M	o	Right coronary artery; circumflex coronary artery; anterior descending coronary artery	,,	,,	o	+
5	63	M	+	Right coronary artery	,,	,,	+	+
6	34	M	o	Anterior descending coronary artery; right coronary artery	,,	,,	+	o
7	40	M	o	Right coronary artery	,,	,,	o	+
8	53	M	+	Anterior descending coronary artery; right coronary artery; circumflex coronary artery	,,	,,	+	o
9	53	M	o	Right coronary artery	,,	,,	+	+
10	43	M	o	Right coronary artery	,,	,,	o	+
11	49	M	+	Anterior descending coronary artery; right coronary artery	,,	,,	o	+
12	54	F	o	Anterior descending coronary artery; right coronary artery; circumflex coronary artery	,,	,,	+	o
13	52	M	o	Right coronary artery; circumflex coronary artery	,,	,,	o	+

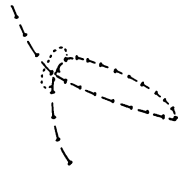* Location of 3+ lesion.
† Resting only.

T LOOP VECTOR
HORIZONTAL PLANE

A. NORMAL RESTING
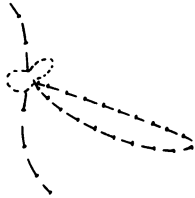
B. NORMAL POST-EXERCISE

C. ABNORMAL POST-EXERCISE

FIG. I *Diagram of normal and ischaemic T loops.*

FIG. 2 *Positive electrocardiogram and positive vectorcardiogram from a patient with severe (3 +) coronary artery disease.*

and abnormal postexercise T loop. Fig. 2–5 illustrate the correlation between the electrocardiogram, vectorcardiogram, and coronary arteriogram in 4 patients.

Discussion

The cause of false positive postexercise electrocardiogram and vectorcardiogram tracings is not clear. Hypokalaemia, digitalis effect, and J point depression can mimic myocardial ischaemia on the electrocardiogram and cause errors of interpretation (Hurst and Logue, 1970). Five false positive electrocardiograms and three false positive vectorcardiograms occurred in patients who were receiving digitalis. None of these patients was hypokalaemic. Angina pectoris and myocardial ischaemia have been reported in patients with apparently normal coronary arteriograms (Likoff, Segal, and Kasparian, 1967; Lim *et al.*, 1970). It is possible that some of our patients fall into this category.

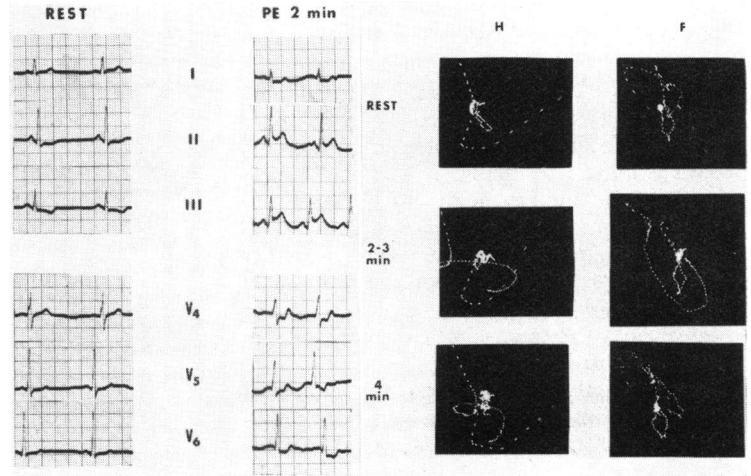The large number of false negative electrocardiograms merely reflect the inaccuracy and insensitivity of the Master's postexercise electrocardiogram. Our percentage of false negative postexercise electrocardiograms (41%) compares very closely to Most *et al.* (1969) (42%). The standard vectorcardiographic tracing has improved the diagnostic accuracy of the standard electrocardiogram. The postexercise vectorcardiogram also provides more information than a standard postexercise electrocardiogram. The postexercise vector T loop is apparently a more sensitive indicator of myocardial ischaemia and lends itself to critical analysis. Accur-

FIG. 3 *Positive electrocardiogram and negative vectorcardiogram in a patient with normal coronary arteriograms.*
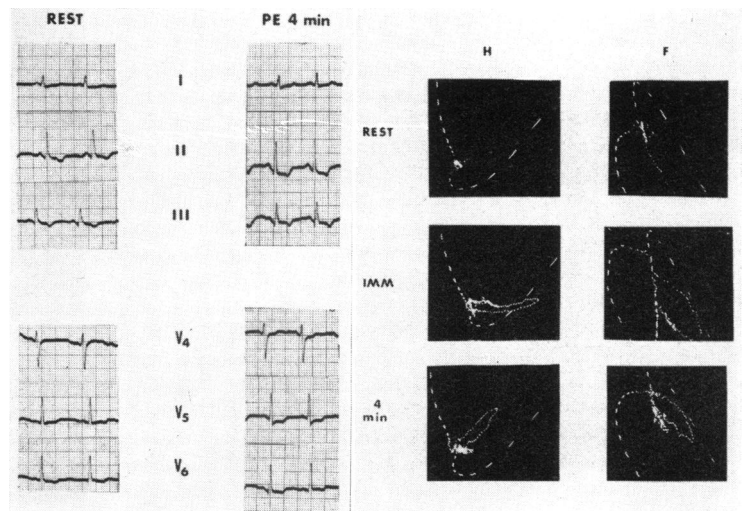
ate T loop length-width ratio measurements can be performed easily on vectorcardiographic T loop recordings. On the other hand, many of the electrocardiograms were difficult to interpret because of baseline abnormalities and equivocal ST depression after exercise. This is illustrated in Fig. 4. The Table summarizes the findings in the 13 patients with severe coronary artery disease, negative electrocardiogram, and positive vector. Neither the presence of digitalis nor the location of the coronary artery lesion accounts for the discrepancy between the electrocardiogram and vectorcardiogram.

The length-width criteria for abnormal vectorcardiographic T loops have been previously established (Chou *et al.*, 1964) and our data correlate well with those criteria. In addition, conspicuous opening of the vectorcardiographic T loop does not occur in normal individuals after exercise (Isaacs *et al.*, 1968) and in our study these criteria further improved the diagnostic accuracy of the postexercise vectorcardiogram. Despite previous reports (Isaacs *et al.*, 1968), direction of T loop rotation, terminal slowing, and T loop angle were not helpful in determining the presence of myocardial ischaemia in our series. In general, the ischaemic T loop was widely open with a characteristic horseshoe shape. However, length-width ratio and ST segment opening measurements permitted more precise determination of vectorcardiographic T loop abnormalities.
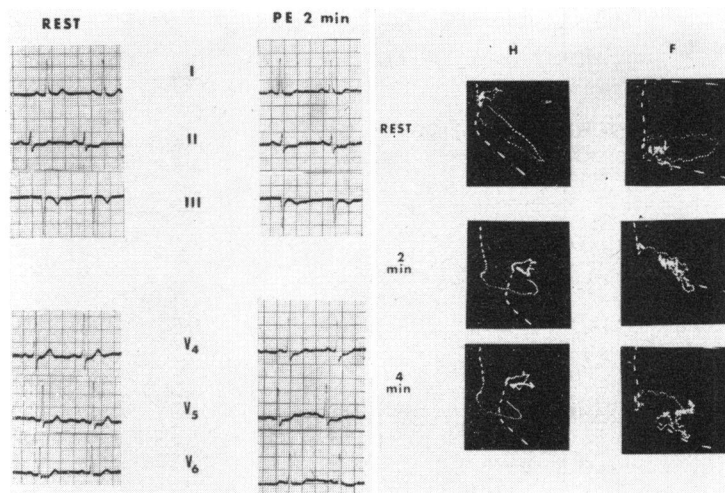

FIG. 4   *Borderline positive electrocardiogram and clearly positive vectorcardiogram in a patient with angiographically severe (3+) coronary artery disease.*

In our experience, the postexercise vectorcardiographic T loop has provided a simple, accurate, non-invasive method for predicting the presence of severe coronary artery disease. Its diagnostic accuracy is apparently superior to the standard postexercise Master's electrocardiogram. The value of the postexercise vectorcardiogram in screening large numbers of patients with suspected coronary artery disease is apparent.

FIG. 5   *Negative electrocardiogram and positive vectorcardiogram in a patient from the Table (Case 3) with severe (3+) coronary artery disease.*
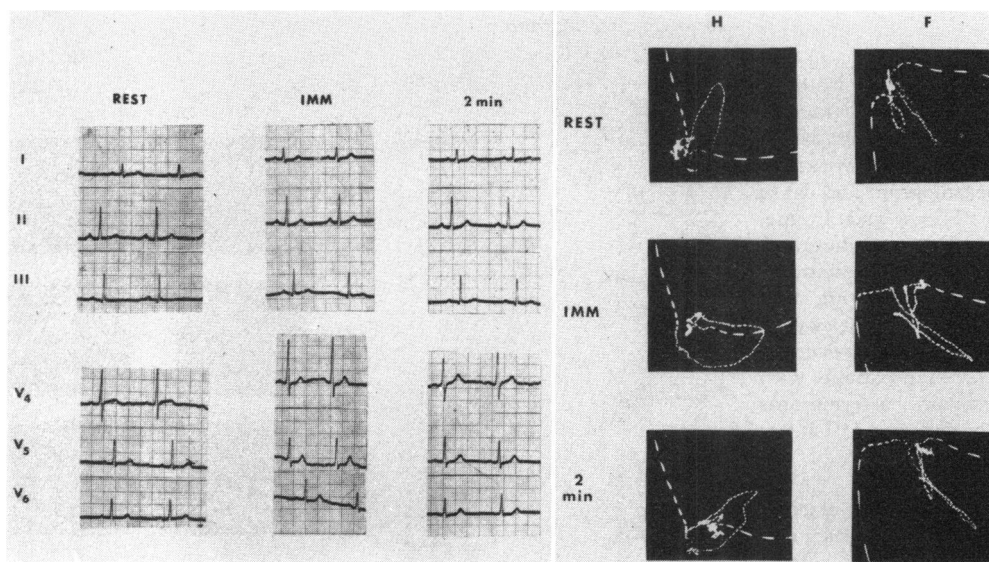
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